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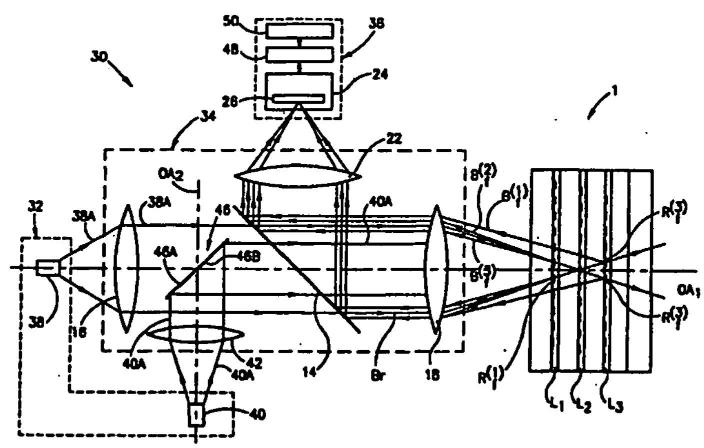

(57) Abstract

Reading method and apparatus are presented for reading information in a three-dimensional information carrier. The carrier is formed with a plurality of spaced-apart data regions, each surrounded by surrounding regions, wherein the data regions are made of a substantially fluorescent material and the surrounding regions are made of a substantially optically transparent material, with respect to a predetermined incident radiation. The reading apparatus comprises an illumination unit, a light directing optics and a detector unit. The predetermined incident radiation is produced for scanning the information carrier and providing output fluorescent radiation having certain parameters. The light directing optics provides such a propagation of the incident radiation that the fluorescent radiation produced at a location within the vicinity of a focal point of the light directing optics has at least one parameter different from the fluorescent radiation produced at any other location inside the carrier. The detector unit comprises filtering means, so as to enable solely the different fluorescent radiation produced at the location within the vicinity of the focal point to be sensed.

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Reading/Recording Method and Apparatus for Three-Dimensional Information Carrier

FIELD OF THE INVENTION

The present invention is in the field of scanning techniques and relates to a method and an apparatus for reading data in a three-dimensional information carrier.

BACKGROUND OF THE INVENTION

There is a great variety of scanning systems for reading/recording information in an information carrier, such as optical disk or optical card. A system of this kind typically comprises an illumination means, light directing optics and a detection means.

It is the common goal of such systems to increase the signal-to-noise ratio of the detected data. This problem becomes more significant when dealing with a three-dimensional information carrier formed of a plurality of information carrying layers in which information is presented in the form of spaced-apart "data spots". It is known that such a multi-layer fashion of recording information in a recording medium enables the amount of stored information to be significantly increased, as compared to that of a single layer carrier.

A three-dimensional information carrier and a reading device therefor are disclosed for example in U.S. Patent No. 4,090,031. The information carrier comprises a substrate and a plurality of data layers provided on one side of the substrate. Each of the layers comprises data tracks formed of lines of data spots. The data spots are formed of either binary coded digital information or frequency or pulse length modulated analog information, which is photographically recorded.

According to one approach disclosed in the above patent, the data spots are light reflective, being formed of light reflecting metal material having a reflecting index different from that of the layers. Selection of one data track for reading is accomplished by changing the focus of a reading light beam from one data layer to another. The main drawback of this approach is unavoidable multiple reflection and diffraction produced by different layers, resulting in the undesirable crosstalk affecting the signal-to-noise ratio. Practically, for that reason, such a "reflective" three-dimensional information carrier cannot be formed with more than two-three information layers. In other words, information recorded in a "reflective" information carrier is too limited.

By an alternative approach, making the data spots of different photoluminescent materials having different optical properties has been proposed. In this case, the illumination means includes a suitable source of "white" light of many frequencies to illuminate different layers by reading beams of different wavelengths. The detection means includes different colored filters accommodated in front of numerous detectors, each associated with a corresponding one of the data layers. It is evident that this technique significantly complicates the manufacture of both the information carrier and reading device used therewith.

SUMMARY OF THE INVENTION

There is accordingly a need in the art to overcome the disadvantages of the conventional reading/recording techniques by a novel apparatus for recording and reading in a three-dimensional information carrier.

It is a major object of the present invention to provide such an apparatus that enables to eliminate or at least substantially reduce an undesirable crosstalk between data spots located in different layers of the information carrier.

There is provided according to one aspect of the present invention a reading apparatus for reading information in a three-dimensional information carrier formed with a plurality of spaced-apart data regions, each surrounded by surrounding regions, wherein the data regions are made of a substantially fluorescent material and the surrounding regions are made of a substantially optically transparent material with respect to a predetermined incident radiation, the apparatus comprising:

(a) an illumination unit producing said incident radiation for scanning the information carrier, so as to provide output fluorescent radiation having certain parameters,

(b) a light directing optics accommodated in the optical path of the incident radiation and focusing said incident radiation on a focal point located inside said carrier, the light directing optics being capable of providing the output fluorescent radiation produced at a location within the vicinity of said focal point having at least one of said certain parameters different from the output fluorescent radiation produced at any other location inside the carrier; and

(c) a detector unit sensing different output fluorescent radiation produced at the location within the vicinity of said focal point, and generating data representative thereof.

The main idea of the present invention consists of the following. The scanning of the information carrier is based on the known principles of a heterodyne detection associated solely with the vicinity of the focal point. To this end, the incident radiation impinging onto the information carrier is in the form of first and second coherent light components having frequencies ω_1 and ω_2, respectively, with the frequency difference ω_{12}. The light directing optics provides such propagation of the first and second light components that they are spatially separated everywhere within the information carrier, except for the vicinity of the focal point where they are mixed with each other. When the data region becomes located within the vicinity of the focal point, the fluorescent medium representing a nonlinear element acts like a heterodyne detection receiver with respect to the mixed incident light components of different frequencies.

It is known that, when such coherent beams with different frequencies overlap, they produce an interference frequency, or so-called "beatnote", equal to the frequency difference ω_{12}. The "beatnote" presents periodical changes in the amplitude of an oscillation, which are caused by the superposition of two harmonic oscillations having slightly different frequencies. This is owing to the changes of the phase difference between two oscillations. Such a signal mixture, when interacting with a nonlinear element (receiver), produces an output signal (fluorescence) which represents the selected location at lower (RF) frequencies.

Hence, a signal, produced by the fluorescent data region in response to the mixed incident radiation of different frequencies, has the intensity modulated with the beatnote frequency ω_{12}. This modulated fluorescence represents "signal fluorescence" to be detected. Out-of-focus data regions interacting with the incident radiation also produce fluorescence. This fluorescence is considered as "noise fluorescence" and should be prevented from being detected. Owing to the fact that the incident light components

overlap solely in the vicinity of the focal point, the intensity frequency produced by the "mixed" incident radiation differs from that produced by each of the incident beam separately.

Therefore, by providing the detector unit with a sensing means equipped with an appropriate band pass filter, the desired focus-related fluorescent signal is filtered form the undesirable fluorescent noise. Thus, high signal-to-noise ratio is achieved.

The light directing optics comprises a beam splitter mounted in the optical path of the incident and fluorescent radiation and transmits one of them, while reflecting the other. The detector unit comprises the sensing and filtering means. The latter includes a spectral filter for separating and transmitting the fluorescent radiation, and a spatial filter operating in a heterodyne detection mode for transmitting solely the "signal fluorescence", which has a frequency different from the "noise fluorescence".

By one embodiment of the invention, the illumination unit comprises two light sources generating first and second coherent frequency-different beams, respectively. The light directing optics includes a focusing lens arrangement and an annular-shaped mirror accommodated in the optical paths of the first and second beams. The annular shaped mirror cuts off the central portion of the first beams, allowing the peripheral portion of the first beam to continue its propagation towards the information carrier, and reflects the second beam to form the second light component propagating within the central part of the first light component.

By another embodiment of the invention, the illumination unit comprises a single light source for generating a beam of light having the frequency ω_1. In this case, the light directing optics comprises a first and second annular-shaped mirrors and a local oscillator. The annular-shaped mirrors are symmetrically identical with respect to a plane perpendicular to the direction of the beam's propagation. The local oscillator may be in the

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form of a mirror accommodated out of the optical path of the beam and mounted for reciprocating movement along an axis substantially perpendicular to the direction of propagation of the beam. The first annular-shaped mirror splits the beam into first and second light components formed, respectively, by peripheral and central parts of the beam. The first annular-shaped mirror reflects the second light component onto the oscillating mirror, while the first light component propagates towards the information carrier. The oscillating mirror shifts the frequency of the second light component to be: $\omega_2 = \omega_1 + \omega_{12}$, and reflects it onto the second annular shaped mirror. The latter reflects the second light component so as to provide its propagation within the cut off central part of the generated beam.

The advantages of the present invention are thus self-evident. Indeed, the provision of the incident light components of different frequencies, impinging onto the fluorescent non-linear medium, enables the known heterodyne detection to be provided. The provision of the light directing optics designed so as to spatially separate the incident beams anywhere except for the focal point, enables this heterodyne detection to be associated solely with the addressed in-focus data regions.

The information carrier may be an optical memory device, such as disk, card, etc., and may be manufactured by any suitable technique, for example such as that disclosed in co-pending U.S. Patent Application Serial No. 08/956,052 assigned to the assignee of the present application. Alternatively, the information carrier may be a tissue carrying body, wherein the above apparatus enables to locate this tissue within a diagnostic region inside the body.

According to another aspect of the present invention, there is provided a method for reading information in a three-dimensional information carrier formed with a plurality of spaced-apart data regions, each surrounded by surrounding regions, wherein the data regions are made of a substantially

fluorescent material and the surrounding regions are made of a substantially optically transparent material, with respect to a predetermined incident radiation, the method comprising the steps of:

(i) producing said incident radiation for scanning the information carrier and providing output fluorescent radiation having certain parameters,

(ii) defining a focal point inside the carrier and focusing said incident radiation onto said focal point, so as to provide the output fluorescent radiation at a location within a vicinity of said focal point having at least one of said certain parameters different from the output fluorescent radiation produced in any other location inside the carrier;

(iii) sensing the different fluorescent radiation produced at the location within the vicinity of said focal point, while suppressing the output fluorescent radiation coming from any other locations, and generating data representative thereof.

More specifically, the present invention is used for reading information in a three-dimensional optical memory disk and is therefore described below with respect to this application.

BRIEF DESCRIPTION OF THE DRAWINGS:

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 schematically illustrates the main principles of operation of a conventional scheme for reading information in a three-dimensional fluorescent information carrier;

Fig. 2 illustrates the main components and principles of operation of a reading apparatus, constructed according to one embodiment of the invention, suitable for reading recorded information in the memory device of Fig. 1;

Fig. 3 is a graphical illustration of the main principles of operation of a detector unit of the apparatus of Fig. 2; and

Fig. 4 illustrates the main components and principles of operation of a reading apparatus, constructed according to another embodiment of the invention, suitable for reading recorded information in the memory device of Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In order to more clearly illustrate unique feature of the present invention, it would be reasonable to consider a conventional technique applied for reading in a three-dimensional fluorescent optical memory device. Fig. 1 illustrates a three-dimensional optical memory disk, generally designated **1**, comprising several information layers, for example, three layers L_1, L_2 and L_3, formed on a substrate **2**. The adjacent information layers are spaced by intermediate layers $L^{(1)}$ and $L^{(2)}$, respectively, made of substantially optically transparent material. Recorded information stored in the data layers is in the form of a pattern having a plurality of spaced-apart data regions, generally at R_f, containing fluorescent material, the data regions being spaced by substantially optically transparent regions R_t. A conventional system, generally at **4**, is associated with the disk **1** for reading out the information recorded therein. The system **4** comprises an illumination unit generally at **6**, a light directing optics **8** and a detector unit **10**.

The illumination unit **6** includes a light source **12** that generates a reading beam B_r having frequency ω_r. The interaction between the reading beam B_r and the fluorescent data regions R_f produces fluorescent radiation B_f having frequency ω_f different from that of the reading beam.

The light directing optics **8** comprises a beam splitter **14**, which is transparent with respect of radiation having frequency ω_r, thereby transmitting the reading radiation B_r and reflecting the fluorescent radiation

B_f returned from the disk **1**. Converging lenses **16** and **18** are accommodated at opposite sides of the beam splitter **14**, the light source and the addressed layer, for example the layer L_2, being positioned in the focal planes of the lenses **16** and **18**, respectively. Thus, the lens **16** directs the reading radiation B_r in the form of a parallel beam onto the beam splitter **14**, while the lens **18** focuses the reading beam onto a focal point **20** located on the addressed layer L_2. A similar lens **22** is accommodated in the optical path of the fluorescent radiation B_f reflected from the reflecting surface of the beam splitter **14** so as to focus the fluorescent radiation onto the sensing surface of the detector unit **10**. The beams' propagation is shown here schematically, solely to facilitate the illustration of the main components of the system **4** and main principles of its operation.

The detector unit **10** comprises a suitable sensor **24** and a spectral filter **26** located in front of the sensor **24**. The filter **26** may be of any known kind executing direct detection, namely operating so as to allow the propagation therethrough of the known spectrum of the fluorescent radiation, and to prevent any other radiation (reading) from reaching the sensor **24**. The latter operates in a conventional manner for providing electrical output representative of the light components received.

As shown, the incident radiation B_r propagates through the disk **1** and interacts with several fluorescent regions $R_f^{(1)}$, $R_f^{(2)}$ and $R_f^{(3)}$ locating in, above and below the addressed point **20**, respectively, producing the fluorescent radiation components $B_f^{(1)}$, $B_f^{(2)}$ and $B_f^{(3)}$. Each of the radiation components $B_f^{(1)}$, $B_f^{(2)}$ and $B_f^{(3)}$ reaches the sensor **24**. However, only the component $B_f^{(2)}$ associated with the addressed in-focus region, represents a desired signal, while the fluorescent radiation components $B_f^{(1)}$ and $B_f^{(3)}$ associated with any other out-of-focus region represent undesirable noise. Consequently, the system **4** suffers from unavoidable crosstalk between data regions located in different layers.

It is known that the power of fluorescent radiation is proportional to that of the reading radiation. If the disk contains N information layers, the noise power (i.e. fluorescence generated in out-of-focus layers) is *(N-1)* times larger than a power of the signal (i.e. fluorescence generated in the in-focus layer). Thus, in a disk having significant number of information layers, the signal-to-noise ratio will be negligibly small which impedes the reading of information stored therein.

Reference is made to Fig. 2, illustrating an apparatus **30** constructed and operated according to one preferred embodiment of the present invention for reading information in the disk **1**. Same reference numbers are used for identifying those components, which are identical in the system **4** and apparatus **30**, in order to facilitate understanding. The apparatus **30** comprises an illumination unit **32**, light directing optics **34** and detector unit **36**. It should be noted, although not specifically shown, that a suitable drive means is typically provided for driving the rotation of the disk **1** about its axis, and for driving a reciprocating movement of the disk with respect to the incident radiation, so as to provide scanning of the inside of the disk **1**.

The illumination unit **32**, in distinction to that of the system **4**, comprises first and second radiation sources, designated **38** and **40**, respectively. Similarly, the beams propagation is illustrated schematically. The first radiation source generates a first coherent light component of the incident radiation **38a** having frequency ω_1. The second radiation source **40** generates a second coherent light component of the incident radiation **40a** having frequency ω_2, differing from that of the first light component as follows:

$$|\omega_2 - \omega_1| = \omega_{12}$$

The light directing optics **34** comprises the partially transparent beam splitter **14**, converging lenses **16**, **18** and **22**, and additional converging lens **44** and mirror **46** having non-reflective and reflective outer surfaces **46a** and **46b**. It should be noted that the lenses **16**, **18** and **44** could be reflective or holographic. The mirror **46** is accommodated in the optical path of the first and second light components of the incident radiation **38a** and **40a**, downstream of the lens **16**. The propagation of beams 38a and 40a define optical axis $\mathbf{OA_1}$ and $\mathbf{OA_2}$, respectively. The mirror **46** has an annular shape and is centered at the intersection of the optical axes $\mathbf{OA_1}$ and $\mathbf{OA_2}$. The diameter of the mirror **46** is smaller than the dimensions of the lens **16**. Thus, non-reflective surface **46a** of the mirror **46** cuts off a central portion of the first beam **38a**, defined by the diameter of the mirror **46**, and allows the propagation of the peripheral portion of the beam **38a** towards the disk **1**. The reflective surface **46b** of the mirror **46** reflects the second beam **40a** to propagate within the central portion of the beam **38a** along the optical axis $\mathbf{OA_1}$.

Thus, spatially separated first and second beams **38a** and **40a** propagate towards the disk **1**. The design of the light directing optics **34** provides the following relationship between the beams **38a** and **40a**. The beam **40a** propagates within a paraxial area of the optical axis $\mathbf{OA_1}$, the numerical aperture N_2 being up to 0.2-0.5, while the beam **38a** propagates distant to the optical axis $\mathbf{OA_1}$ occupying an annular cone which has the numerical aperture N_1 higher than N_2.

The beams **38a** and **40a** pass through the beam splitter **14** and are focused in the focal point **20**, by the lens **18**. As shown, each of the first and second beams **38a** and **40a** interacts with the fluorescent regions $\mathbf{R_f^{(1)}}$, $\mathbf{R_f^{(2)}}$ and $\mathbf{R_f^{(3)}}$ located below, in and above the focal point **20**, producing output fluorescent radiation $\mathbf{B_f^{(1)}}$, $\mathbf{B_f^{(2)}}$ and $\mathbf{B_f^{(3)}}$. The beam splitter **14** reflects the fluorescent radiation to propagate towards the detector unit **36**.

The detector unit **36** comprises the sensor **24** equipped with the spectral filter **26**, and additionally includes a band pass filter **48** coupled to an electronic unit **50**, the function of which will be described more specifically further below.

The beams **38a** and **40a** overlap in the vicinity of the focal point **20**. As known, the superposition of the beams **38a** and **40a**, having different frequencies ω_1 and ω_2, produces a modulation of light intensity with a so-called "beatnote" frequency defined by the difference between the frequencies ω_1 and ω_2, i.e. the frequency ω_{12}. In other words, the phase difference φ of the coherent beams **38a** and **40a** is modulated in time with a certain period T, wherein:

$$T = 2\pi / \omega_{12}$$

Owing to the coherence of the beams **38a** and **40a**, the intensity of the incident radiation within the small region where the incident beams overlap has "beats" with the same period **T**.

The interaction between the intensity-modulated incident radiation with the fluorescent medium, representing a non-linear element, produces fluorescent radiation $\mathbf{R_f}^{(2)}$ whose intensity changes with the same frequency ω_{12}. The intensity changes frequency ω_{12} of the fluorescent signal $\mathbf{B_f}^{(2)}$ generated by the region $\mathbf{R_f}^{(2)}$ where the incident beams **38a** and **40a** overlap (i.e. in-focus region) differs from that of the fluorescent signals $\mathbf{B_f}^{(1)}$ and $\mathbf{B_f}^{(3)}$ associated with the regions $\mathbf{R_f}^{(1)}$ and $\mathbf{R_f}^{(3)}$ where the incident light components **38a** and **40a** are separated from each other (out-of-focus regions). In other words, the in-focus fluorescent radiation (representing "signal fluorescence" to be detected) is "marked" by the "beatnote"

frequency ω_{12}, so as to be distinguishable from any other fluorescent radiation (representing "noise fluorescence") generated in the disk **1**.

Generally, the intensity of "noise fluorescence" I_n coming from all fluorescent regions located in out-of-focus layers is determined as follows:

$$I_n \propto m \cdot (I_1 + I_2)$$

wherein m is the number of information layers; I_1 and I_2 are intensities of the incident light components **38a** and **4)a**. The intensity of "signal fluorescence" I_s coming from the in-focus fluorescent region can be determined as follows:

$$I_s = I_1 + I_2 + 2 \cdot (I_1 \cdot I_2)^{1/2} \cdot \cos(\varphi)$$

Only the "signal fluorescence" intensity I_s contains the product of the incident beams **38a** and **40a** intensities $(I_1 I_2)$, and is modulated with the frequency ω_{12}. This technique enables the signal-to-noise ratio to be significantly increased even in the disk having desirable large number of information layers.

The disk **1** is rotated and the beams of incident radiation **38a** and **40a** scan the addressed layer $\mathbf{L_2}$. As a result, an information fluorescent signal is produced. The information fluorescent signal has certain spectral bandwidth, frequency ω_{12} and amplitude modulation defined by the distribution of the fluorescent regions $\mathbf{R_f}$ in the information layer $\mathbf{L_2}$. This information fluorescent signal is representative of the information stored in the addressed layer and therefore should be detected.

The spectral filter **26** allows the passage of all the fluorescent radiation (spectrum) impinging thereon. The sensor **24** receives the fluorescent radiation and provides electrical signal representative thereof. Hence, the electrical signal that reaches the band pass filter **48** is

representative of fluorescent components coming from the recording regions located in- and out-of-focus (i.e. both the "fluorescent signal" and "fluorescent noise"). The filter **48** operates in the known heterodyne detection mode for allowing the passage solely of the electrical signals representative of fluorescent radiation "marked" by the "beatnote" frequency ω_{12}, i.e. the "signal fluorescence". To this end, the filter **48** is centered on the frequency ω_{12}.

Fig. 3 graphically illustrates, in a self-explanatory manner, the operation of the band pass filter **48**. A lobe **52** represents the output of the filter **48** that inputs the electronic unit **50**. The "beatnote" frequency ω_{12} should be, on the one hand, sufficiently large (more than 1MHz) to enable successful heterodyne detection and fast reading, whilst being relatively small (less than 1GHz) to enable the information fluorescent signal to be modulated at the frequency ω_{12} and detected. Thus, the electronic unit receives the information fluorescent signal generated by the in-focus layer only.

Referring now to Fig. 4, there is illustrated a reading apparatus, generally designated **130**, constructed according to another embodiment of the invention. Similarly, the same reference numbers are used for identifying those components, which are identical in the previously described and present examples. The apparatus **130** comprises an illumination unit **132**, light directing optics **134** and detector unit **36**. Here, in distinction to the apparatus **30**, the illumination unit **132** comprises a single light source **38** that generates the beam of radiation **38a** having the frequency ω_1. Accordingly, the light directing optics **134** comprises an additional annular-shaped mirror **54** and an oscillating mirror **56**. The mirror **54** is accommodated in the optical path of the beam **38a** upstream of the mirror **46** and is symmetrically identical thereto, with respect to a plane perpendicular to the optical axis **OA_1**. The mirror **56** is driven for

reciprocating movement (oscillation) along the axis **OA_2**, with the velocity $V=V(t)$. Obviously any other suitable means may be applied for the same purpose, for example, the surface of a vibrating crystal or an acousto-optical element.

Thus, a central portion, generally at **140a**, of the beam **38a** falls onto the reflective surface **54b** of the mirror **54** and is reflected onto the mirror **56**, while the peripheral portion of the beam **38a** continuous its propagation towards the disk **1**. The mirror **56** reflects the light portion **140a**, which is then reflected by the reflective surface **46b** of the mirror **46** and propagates towards the disk **1**. Thus, two spatially separated light components of the incident radiation **38a** and **140a** are provided.

In accordance with the known Doppler effect, the frequency ω_2 of the light component **140a** reflected from the oscillating mirror **56**, is shifted to be:

$$\omega_2 = \omega_1 + 2kV$$

wherein k is the wave vector of the incident radiation. The light components **38a** and **140a** pass through the beam splitter **14** and are focused into a focal point **20**, by the lens **18**. The beam **140a** propagates within a paraxial area of the optical axis **OA_1** (N_2 = 0.2-0.5), while the beam **38a** propagates distant from the optical axis ($N_1 > N_2$). The beams **38a** and **140** overlap only in the vicinity of the focal point **20**. The intensity of the "signal fluorescence" I_s may be expressed as follows:

$$I_s = I_1 + I_2 + 2 \cdot (I_1 \cdot I_2)^{1/2} \cdot \cos(2kV)$$

The frequency of the signal intensity beats may vary from 1MHz to 1GHz by changing an angle between the vectors k and V.

It is important to note, although not specifically shown, that the apparatus **30** (or **130**) may be applied for reading information in any other three-dimensional information carrier characterized by the following main feature:

- spaced-apart regions having fluorescent properties with respect to a certain incident radiation, which fluorescent regions are surrounded by optically transparent regions, with respect to this incident radiation.

For example, the information carrier may be the patient's body, and the reading apparatus may be used for detecting and locating an abnormal tissue in the body.

To this end, a photosensitizer is collected in the abnormal tissue of the patient's body. The photosensitizer, when interacting with the appropriate incident radiation, produces fluorescence. The incident light (i.e. its frequency) should satisfy the following conditions:

- produce fluorescence of the photosensitizer;
- have low absorption in the tissue material, to allow for efficient focusing of the incident light components.

High signal-to-noise ratio is achieved due to the heterodyne detection. This allows for relaxing the requirements to photosensitizer absorption difference and enables reduced amount of the photosensititzer to be successfully applied. Based on the data generated by the detector unit, the tissue image is pixel-by-pixel reconstructed using any suitable image processing technique to enable three-dimensional visualization of the diagnostic region.

Those skilled in the art will readily appreciate that many modifications and changes may be applied to the invention as hereinbefore exemplified without departing from its scope defined in and by the appended claims.

CLAIMS:

1. A reading apparatus for reading information in a three-dimensional information carrier formed with a plurality of spaced-apart data regions each surrounded by surrounding regions, wherein the data regions are made of a substantially fluorescent material and the surrounding regions are made of a substantially optically transparent material with respect to a predetermined incident radiation, the apparatus comprising:

   (a) an illumination unit producing said incident radiation for scanning the information carrier, so as to provide output fluorescent radiation having certain parameters,

   (b) a light directing optics accommodated in the optical path of the incident radiation and focusing said incident radiation on a focal point located inside said carrier, the light directing optics being capable of providing the output fluorescent radiation produced at a location within the vicinity of said focal point having at least one of said certain parameters different from the output fluorescent radiation produced at any other location inside the carrier;

   (c) a detector unit sensing the different output fluorescent radiation produced at the location within the vicinity of said focal point, and generating data representative thereof.

2. The apparatus according to Claim 1, wherein said incident radiation comprises two coherent light components having different frequencies.

3. The apparatus according to Claim 1, wherein said certain parameters of the fluorescent radiation comprises predetermined bandwidth, frequency and amplitude modulation defined by the distribution of the recording regions, said at least one parameter being the frequency of the fluorescent signal defined as frequency difference of said two light components.

4. The apparatus according to Claim 2, wherein said light directing optics comprises splitting means providing an overlapping of said light components solely in the vicinity of the focal point.

5. The apparatus according to Claim 1, wherein said light directing optics comprises a beam splitter accommodated in the optical path of the incident and fluorescent radiation for transmitting one of them.

6. The apparatus according to Claim 1, wherein said detector unit comprises a sensing means and a filtering means.

7. The apparatus according to Claim 2, wherein

- said illumination unit comprises a first radiation source generating a first beam of incident radiation, and a second radiation source generating a second beam of incident radiation;
- said first and second coherent light components being formed by at least portions of said first and second beams, respectively.

8. The apparatus according to Claim 7, wherein said light directing optics comprises a splitting means including an annular-shaped mirror accommodated in the optical path of the first and second beams, so as to cut off a portion of the first beam producing said first light component formed by a peripheral portion of the first beam, and to reflect the second beam producing said second light component propagating within said cut off portion of the first beam, so as to provide collinear propagation of the first and second light components.

9. The apparatus according to Claim 2, wherein

- said illumination unit comprises a radiation source producing a beam of a certain frequency;
- said light directing optics comprises a splitting means including first and second annular shaped mirrors and a local oscillator, said first annular-shaped mirror reflecting a central portion of the beam onto the local oscillator and producing said first light component

formed by a peripheral portion of the beam, propagating towards the information carrier, said local oscillator shifting the frequency of the reflected portion of the beam at a certain frequency value and producing said second light component propagating towards the information carrier.

10. The apparatus according to Claim 6, wherein said filtering means comprises a spectral filter separating said fluorescent radiation coming from the information carrier, and a spatial filter operating in a heterodyne detection mode.

11. A method for reading information in a three-dimensional information carrier formed with a plurality of spaced-apart data regions, each surrounded by surrounding regions, wherein the data regions are made of a substantially fluorescent material and the surrounding regions are made of a substantially optically transparent material, with respect to a predetermined incident radiation, the method comprising the steps of:

(i) producing said incident radiation for scanning the information carrier and providing output fluorescent radiation having certain parameters,

(ii) defining a focal point inside the carrier and focusing said incident radiation onto said focal point, so as to provide the output fluorescent radiation at a location within a vicinity of said focal point having at least one of said certain parameters different from the output fluorescent radiation produced in any other location inside the carrier;

(iii) sensing the different fluorescent radiation produced at the location within the vicinity of said focal point, while suppressing the output fluorescent radiation coming from any other locations, and generating data representative thereof.

12. The method according to Claim 11, wherein said incident radiation scanning the carrier comprises two coherent light components having different frequencies.

13. The method according to Claim 12, wherein said producing of the incident radiation comprises emitting first and second beams, said directing comprises:

- cutting off a central portion of the first beam, the first light component being formed of a peripheral portion of the first beam;
- providing the propagation of said second beam within the cut off portion of the first beam, said second beam forming the second light component propagating collinear to said first light component.

14. The method according to Claim 11, wherein said sensing comprises the steps of:

- separating the output fluorescent radiation from said incident radiation;
- separating the different fluorescent radiation produced at the location within the vicinity of said focal point from said output fluorescent radiation.

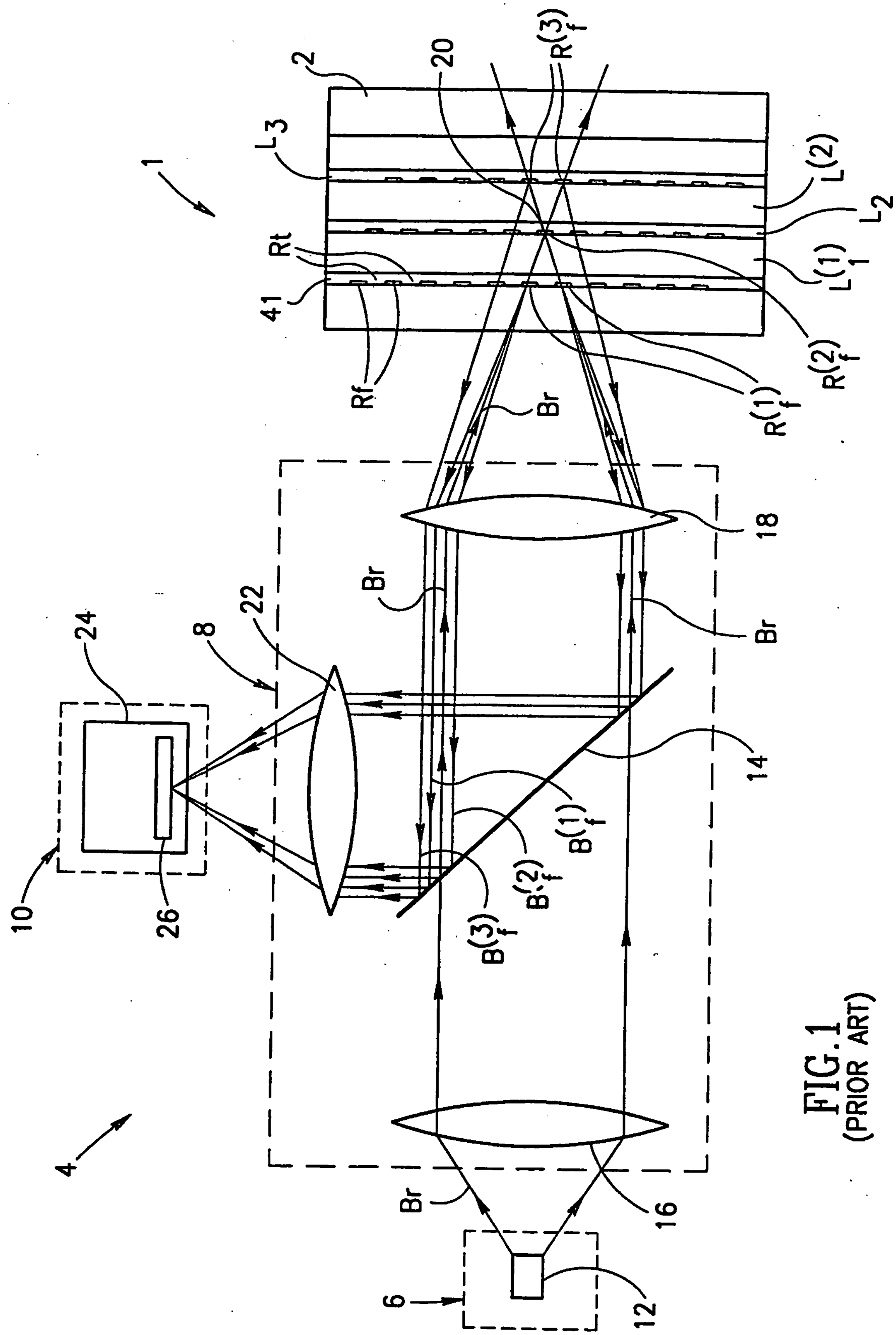
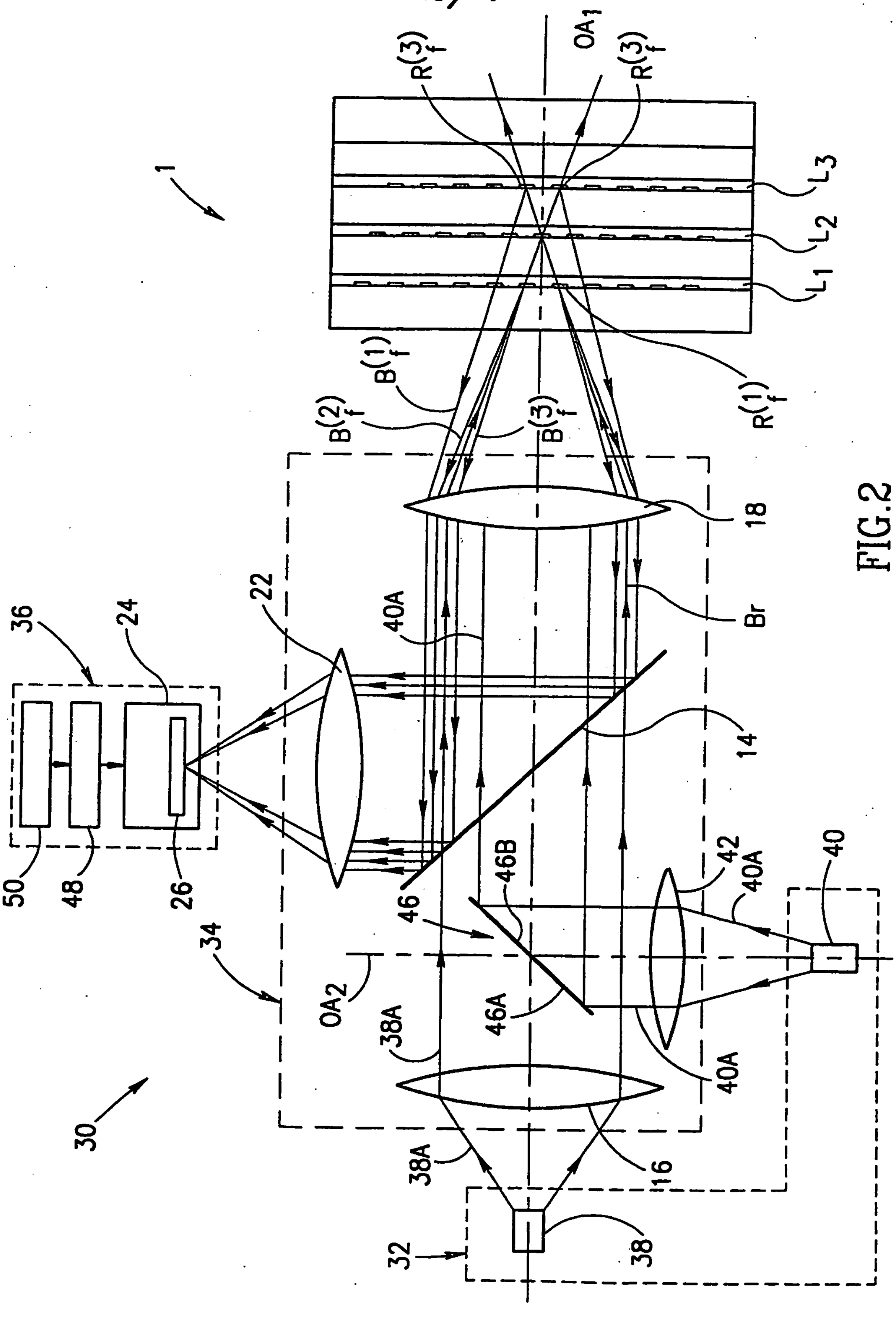


FIG.1
(PRIOR ART)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L2
L3
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22
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26
36
40A
Br
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46A
46B
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40
48
50
34
OA2
38A
16
30
32
38

FIG.2

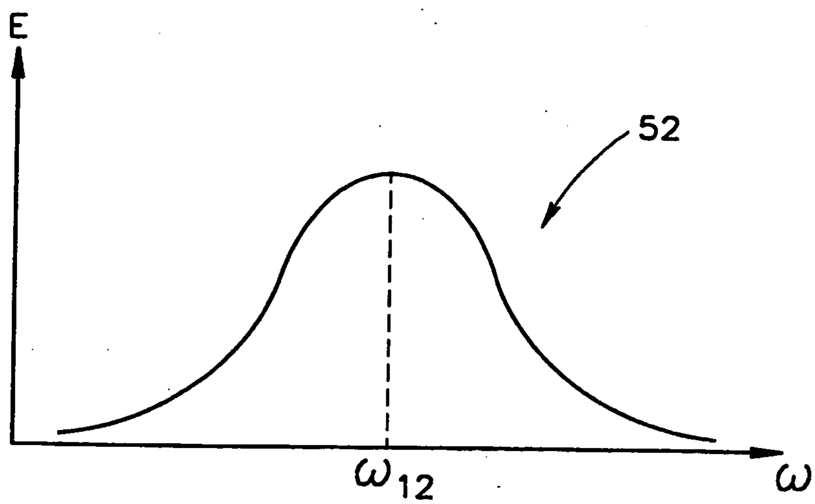
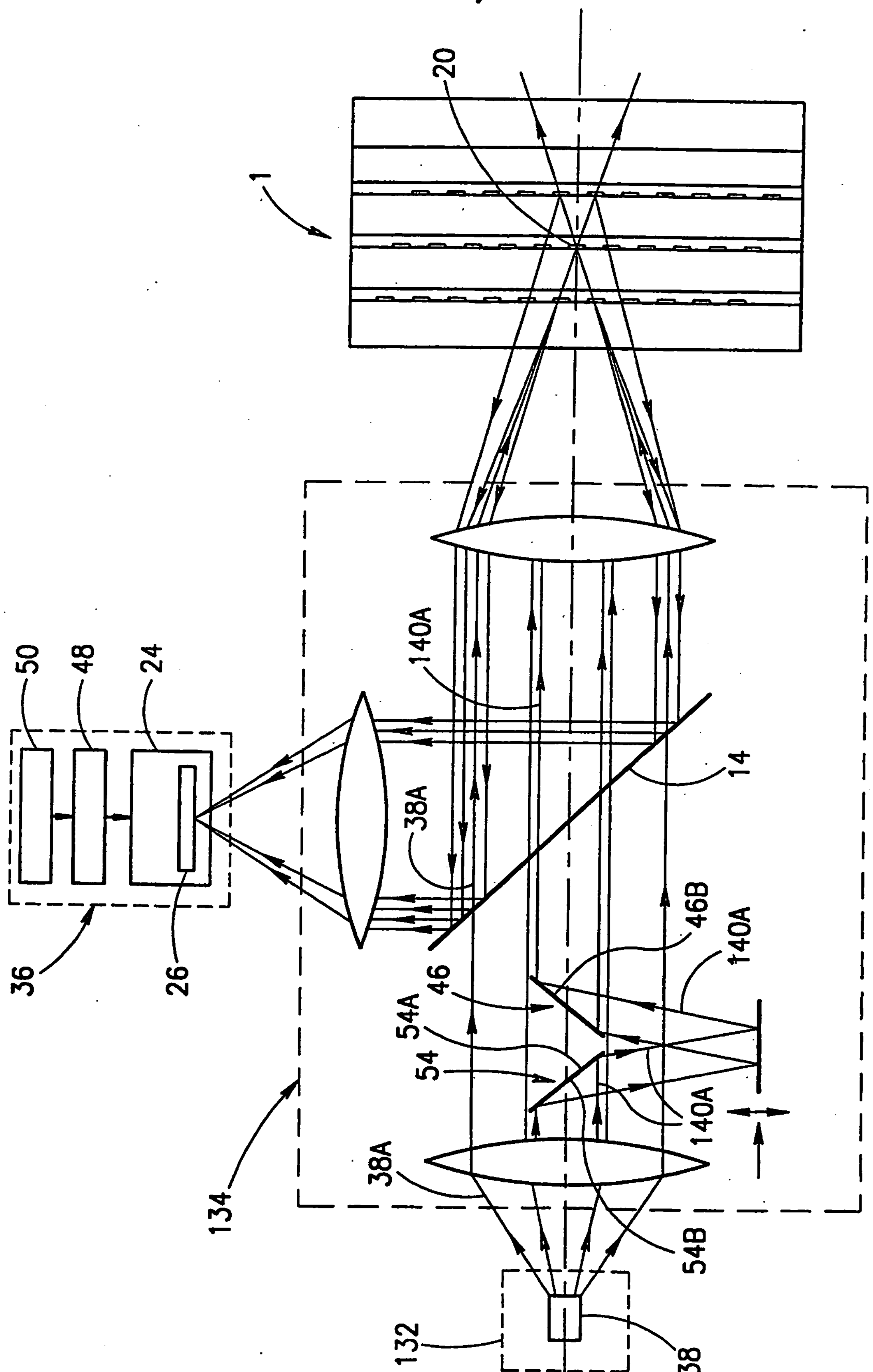


FIG.3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140A
36
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46
54A
54
140A
134
38A
54B
132
38

FIG.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 98/00374

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G11B7/00 G11B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 090 031 A (RUSSELL JAMES T) 16 May 1978 cited in the application see column 3, line 17 - column 7, line 51; figures 1-6 ---	1,3,5, 11,14
Y	EP 0 164 577 A (TOKYO SHIBAURA ELECTRIC CO) 18 December 1985 see page 20, line 9 - line 24 see page 25, line 26 - page 26, line 11; figures 3,6 ---	1,3,5, 11,14
Y	EP 0 354 601 A (PIONEER ELECTRONIC CORP) 14 February 1990 see abstract; figure 1 ---	1,3,5, 11,14
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 October 1998	25/11/1998

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 98/00374

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	DE 44 44 988 A (WENDT ULRICH DR RER NAT HABIL) 20 June 1996 see claims 1,2 ---	1,3,11, 14
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Information on patent family members

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